EXAMINATION OF A DEEP SUBSURFACE MARS POLAR CAP MISSION TO ADDRESS CLIMATE HISTORY

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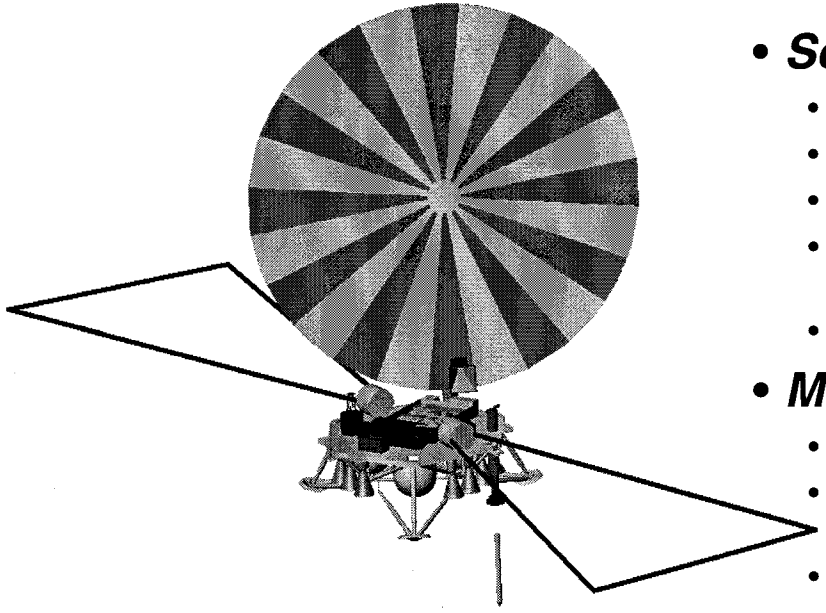
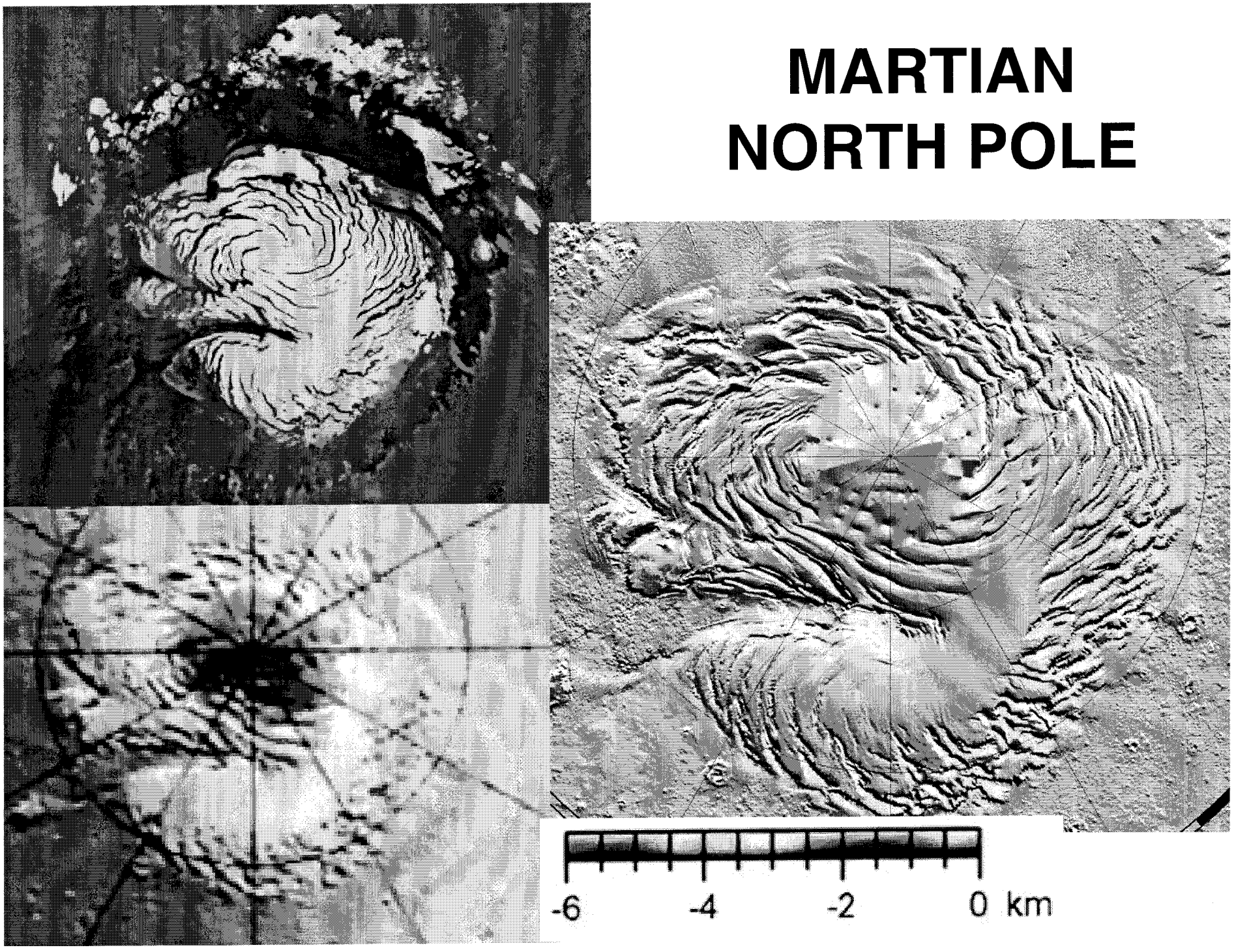
MARS CLIMATE HISTORY MISSION

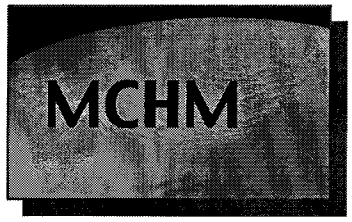


- ***Science Objectives***
  - Determine the Age, Structure, Dust Character of the PLD
  - Determine Composition of ~1 km North Polar Layered Deposits (PLD)
  - Characterize Past Volatile Cycles Related to Atmospheric Evolution
  - Search for Extra-Martian Organic Tracers of the Evolution of the Atmosphere
  - Characterize the PLD-Basement contact
- ***Mission Description***
  - Landing Site: 85-87° North PLD Where Thickness Is ~ 1km
  - Subsurface: Descend / Sample to ~1000 m Depth; Return to Surface, By Capillary, <100-μm Samples for Analysis
  - Mission: Launch '09 or Later, SEP, ~2.5 yr Flight, >100^{d} Daylight
  - Telecom: Direct Earth Comm. or MicroSats Network
  - Option: Archive Earth Return Sample - Improve Dating (AMS)
- ***Measurement Strategy***
  - Return to Lander, Document, Separate, Concentrate, Analyze and Archive PLD Samples Every 1 m of Depth
  - Measure Water / CO_2 Ratio and C, O and H Isotopic Ratios (MS)
  - Age-date PLD By Determining Luminescence Dates and By Counting Layers
  - Determine Thermal History by Measuring Radical Abundances (EPR)
  - Measure Organic Abundances With EPR and/or MS
  - Subsurface Sounding Using Radar
  - Characterization and Analysis of Dust, Ash, and Meteoritic Grains

- ***Critical Technology and Science Developments***
  - Subsurface Explorer (SSX)
  - Microscopic Sample Analysis Lab
  - Chronometry of PLD
  - Precision Landing Navigation & Hazard Avoidance
  - Properties of Simulated PLD Materials

MARTIAN NORTH POLE

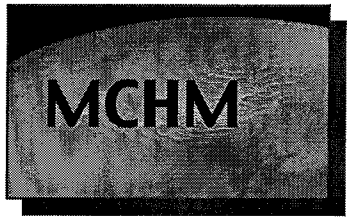




Mars Climate History Mission

FUNDAMENTAL QUESTIONS MARS POLAR CAP SCIENCE

- How Much North Polar Ice Cap Is There?
- What is Its Current Mass Balance State?
- Is/Was the North Polar Cap Part of a Regional Hydrology?
- Was the Polar Cap Different in Mass/Size in Recent Past?
- What are the Dynamics and Thermodynamics of the Polar Caps?



CLIMATE HISTORY MISSION SCIENCE RATIONALE

- **Mars Polar Caps A Site of Significance**
  - **Recent Climate History in Layered Deposits**
  - **Past Connection to Mars Hydrological System**
  - **Past Association with Liquid H_2O**
- **Deep Subsurface Survey Essential**
  - **Surface Deposits Distorted**
  - **Top Layer Influenced Chemically and Radiatively**
- **PLD-Basal Contact Significant to Biohistory**

INSTRUMENTS MAPPED TO SCIENCE THEMES

Science Themes	Science Objectives	Measurements Objectives	Instruments	Measurements
Mars Climate History	Ice Composition	Characterize CO2/H2O Content and Ratios	Mass Spectroscopy	Molecule mass vs abundance
	Atmosphere Evolution	Isotope ratios (C, O, H)	Mass Spectroscopy	Molecule mass vs abundance
	Age of PLD	Cosmogenic Radionuclide Isotope Concentration and Ratios	Accelerator Mass Spectroscopy	
		Age date particles in layers	Luminescence dater	Thermo (TSL), Optical (OSL), IR (IRSL) Stimulated Luminescence
		Count and measure layers	Microscope (10 micron)	Dust and micrometeoroid number density vs. depth
	Thermal History of PLD	Determine peak temperature history each layer	Electron Paramagnetic Resonance	Measure radical abundances vs. depth
		Measure ambient temperature of layers	Thermometer	Temperature
	Search for organics	Detect organic molecules	Mass spectrometer	Identify signature products e.g. CH4, by measuring molecule masses and abundances
		Detect organic molecules	Electron Paramagnetic Resonance	Indentify organic radicals
	Structure of PLD	Subsurface morphology	Ground Penetrating Radar	Returned RF signal time and amplitude
			Microscope (10 micron)	Dust number density vs. depth
	Dust Characterization	Dust number density	Microscope (10 micron)	Count particles
		Dust morphology	Deconvolutional Confocal Microscopy (1 micron)	Image individual grains
		Dust mineralogy	Mossbauer spectroscopy	Chemical and magnetic phases of Iron compounds
			Raman spectroscopy	Spectrum
Volcanic History	Characterize Sulfur Content	Sulfur abundance vs. depth	Mass spectrometer	Molecule mass vs abundance
	Ash characterization	See Dust characterization	See Dust characterization	See Dust characterization
Recent (<1By) Bombardment History	Determine ages of recent terrain	Number density of meteoritic material as function of time	Microscope (10 micron)	Number density vs layer depth
		Isotope ratios (3He/4He)	Mass spectrometer	Molecule mass vs abundance

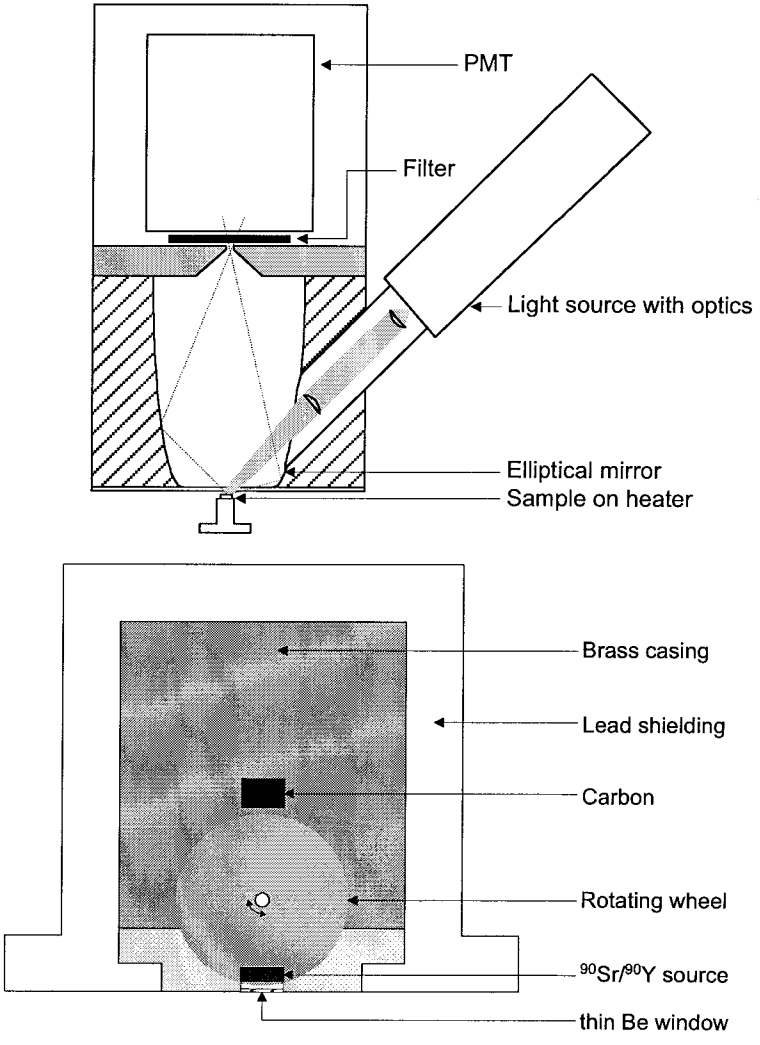
Mars Climate History Mission

SCIENCE DEVELOPMENT ISSUES

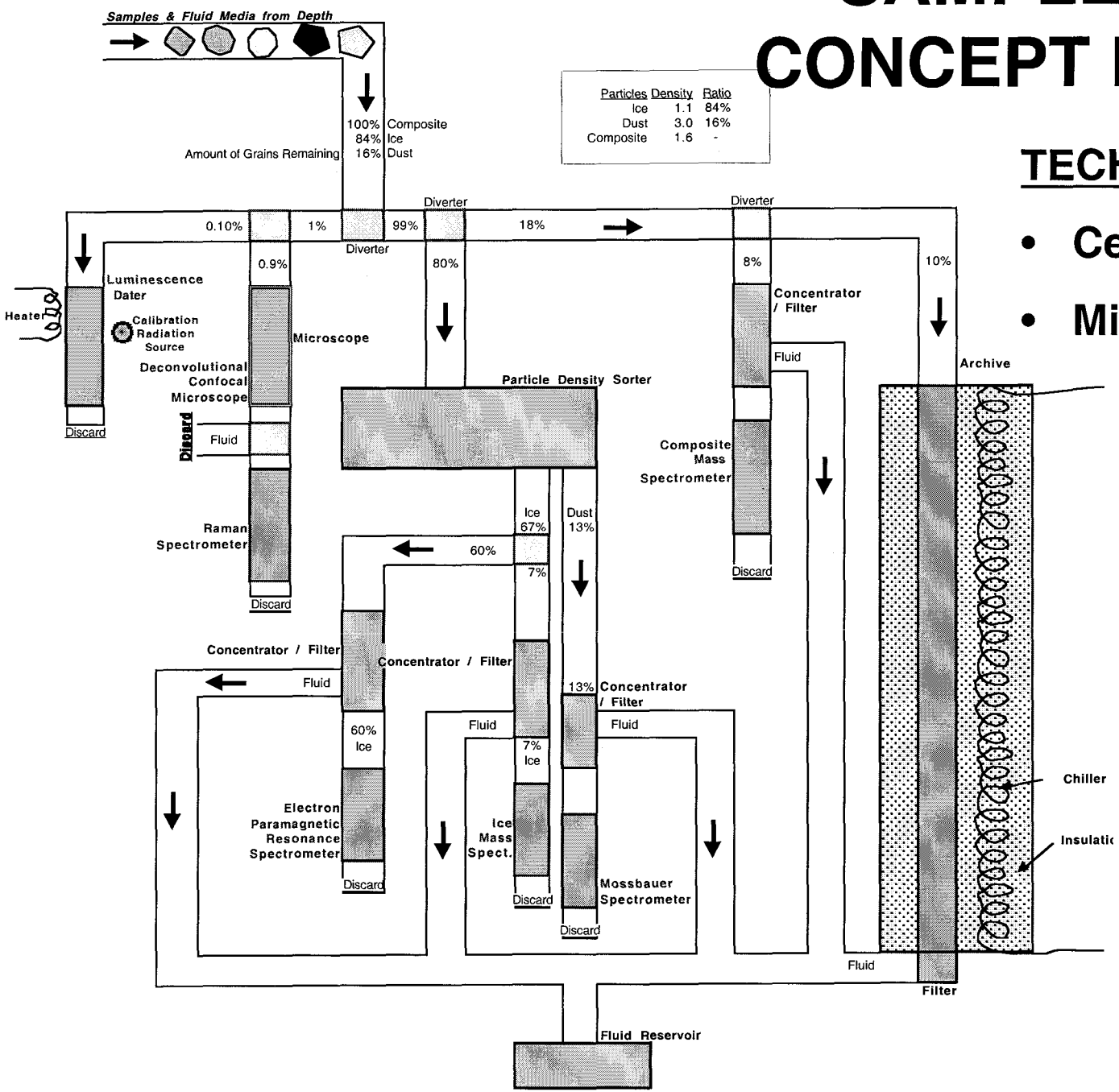
- Chronometry
  - Luminescence Dating One Obliquity Cycle
  - Bootstrap to Extrapolate Into the Deep Past
    - Cosmogenic Abundance Modeling
    - Layer Counting
    - Atmospheric Modeling
- Simulated Mars Polar Cap Material Studies
  - Mechanical, Radiation, Thermal Properties
  - Testing of SSX System and Sample Handling Laboratory

LUMINESCENCE DATER

- **Measurement Objectives**
  - Age Date Particles in Layers
- **Measurement Requirements**
  - Dating of Samples From First 10 m Corresponding to ~100,000 Years
- **Measure Luminescence Signal of a Specimen**
- **Calibrate Each Sample Using Radiation Source**
- **Physical Characteristics**
  - Mass - 5 kg
  - Volume - 2,000 cc
  - Power - 3 W



SAMPLE ANALYSIS CONCEPT FLOW CHART

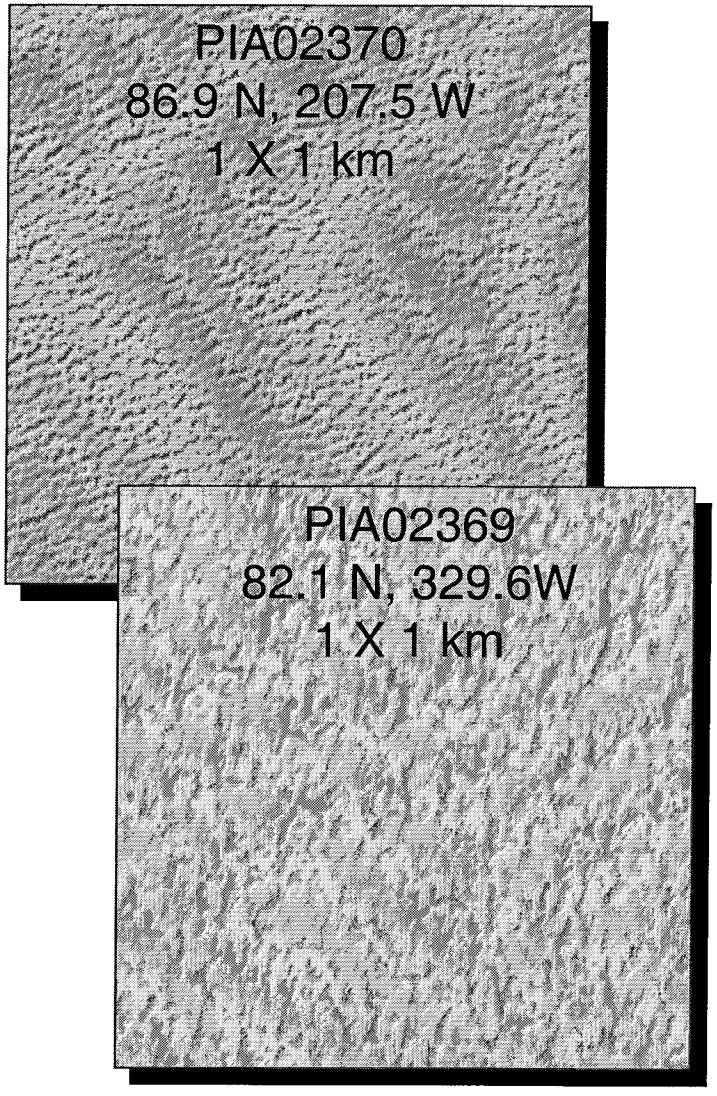


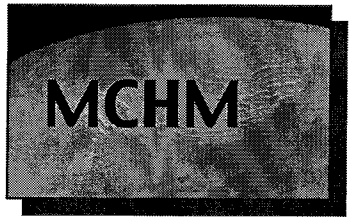
TECHNOLOGY BASE

- Cell Sorting
- Micro (Mini) Fluidics

HAZARD AVOIDANCE

- **Flat North Polar Layered Terrain May Be Very Heavily Pitted With Local Slopes From 10-45°**
- **Hazard Avoidance or Robust Landing Systems May Be Required**

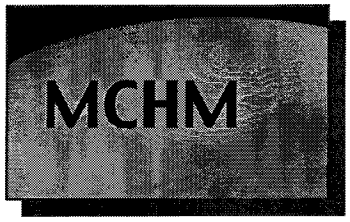




Mars Climate History Mission

KEY MISSION FEATURES

- Reference Mission Launch in May 2009 on Delta II or III
- 5 kW SEP Cruise Stage, ~2.5 yr Flight
- November 2011 Arrival at Start of N. Polar Summer >100d with Sun > 5° Above Horizon
- Landing Site: ~85-87° North PLD Where Thickness Is ~ 1km
- Subsurface: Descend / Sample to ~1000 m Depth; Return to Surface, By Capillary, <100–mm Samples for Analysis
- Telecom: Direct Earth Communications or MicroSats Network
- Option: Archive Earth Return Sample - Improve Dating with Accelerator Mass Spectroscopy (AMS)



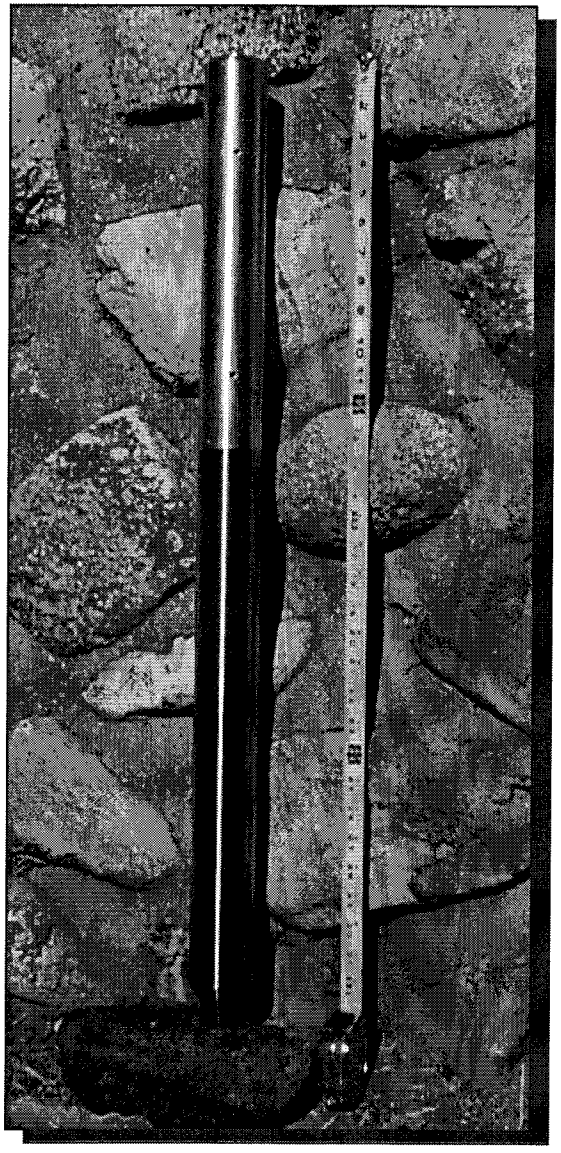
SUMMARY

- **The Climate History of Mars Is a Key Unknown.**
- **The Mars Climate History Mission Addresses All Key Mars Exploration Themes: Water, Climate, Life, and Resources**
- **Several Needed Technologies and Science Development Areas Are Identified and Most Are Currently Being Studied**
- **A Deep Subsurface Mars Exploration Mission Is Within Reach**

MCHM

SUBSURFACE EXPLORER (SSX)

- **Description**
  - Approximately 1 m long, 3.8 cm dia, 20 kg
  - Power Supplied over 1 km fine-wire tether (~100W)
  - Samples returned to surface over 0.1 mm capillary.
- **Percussion Drilling**
  - Hammer Rotation Converted to Linear Action
  - Capable of Penetrating 1 km of Martian North PLD
- **Underlying Technologies**
  - Highly Efficient Patent-pending Percussive Mechanism Converts >70% of Tether Power to Hammer Energy
  - High Voltage Power System Efficiently Delivers Power Over 1 km of Fine Wire.
  - Sampling Acquisition System Uses Fluid to Return <100 micron Particles to Surface Lander.

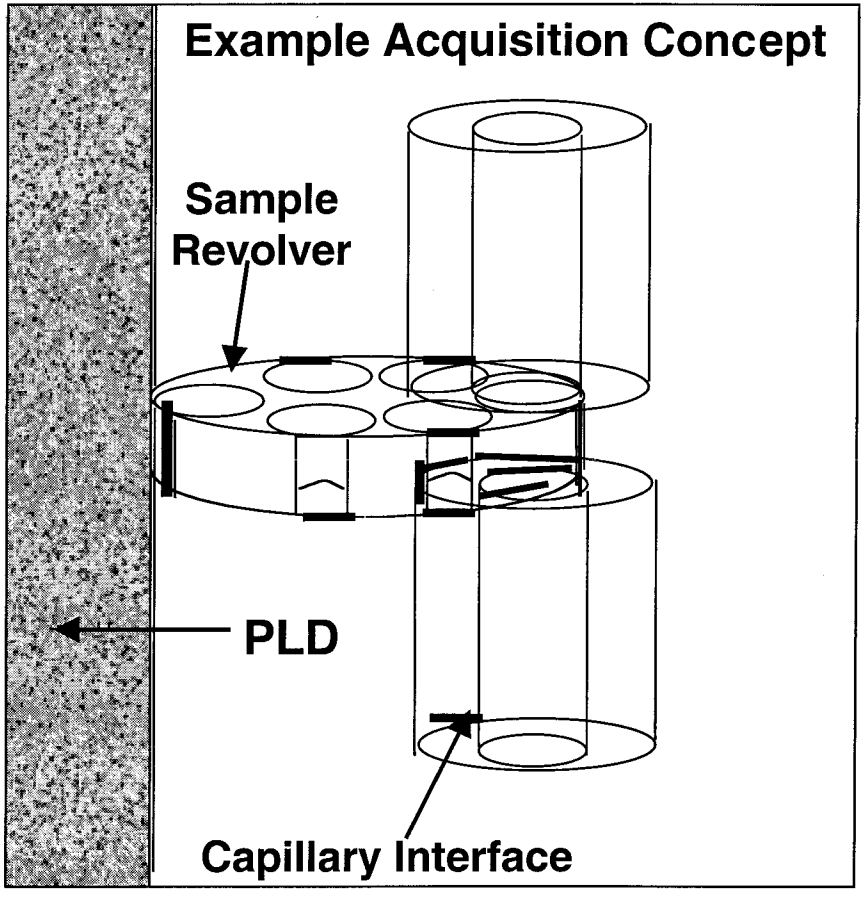


SSX OPERATION

- Nose of Vehicle Has Embedded Hard Particles (e.g. Diamond)
- Shock Wave Pulverizes Medium Against Nose Hard Points
- Pulverized Medium Is Re-compacted Behind Burrower (Less Particles Sent up Capillary)
- Pressure Builds up to Compact Medium to Original Density (Ice Flows Plastically Into Voids)
- Frictional Coefficient Times Sidewall Pressure Determines Energy Loss to Friction

SSX SAMPLE ACQUISITION

- **Fluid(s)**
  - Options- Noble Gasses
    - Argon, Krypton, Xenon
  - Krypton Characteristics
    - Freezes at 116.6K (expected lowest mission temperature 160K)
    - Critical point (liquid-gas phase transition disappears) at 210K, 5.5 MPa, 780 kg/m^3
    - Flow velocity 0.1 m/s thru 100 μ diameter capillary 1000 m long at 10 MPa pressure difference
- **Mechanism Concept**
  - Rotary wheel with cutouts to feed particles into capillary flow



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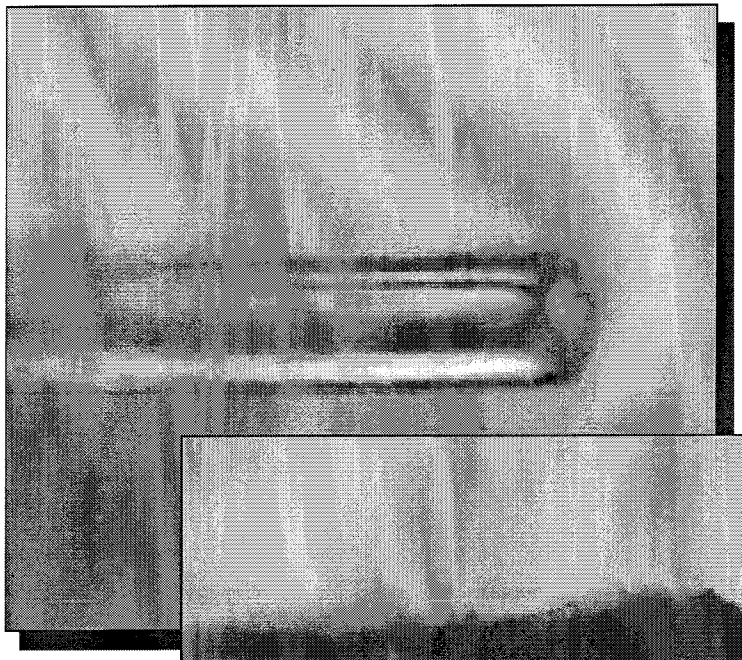
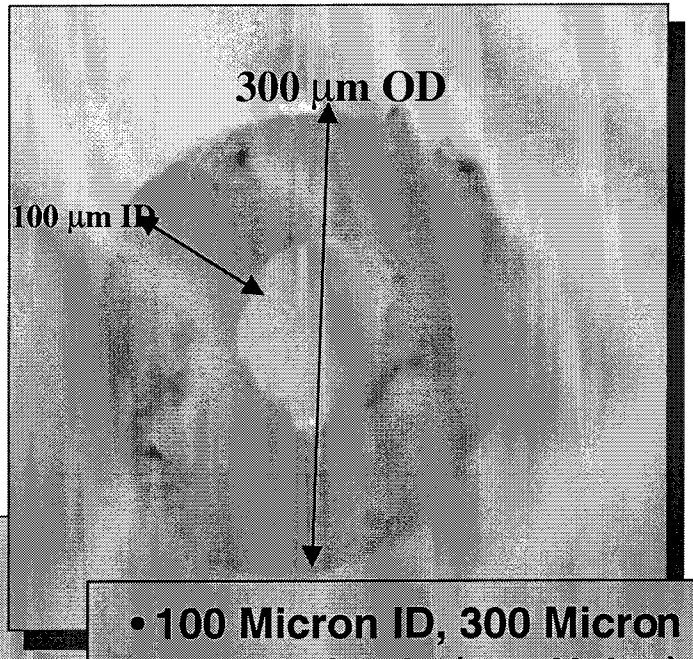
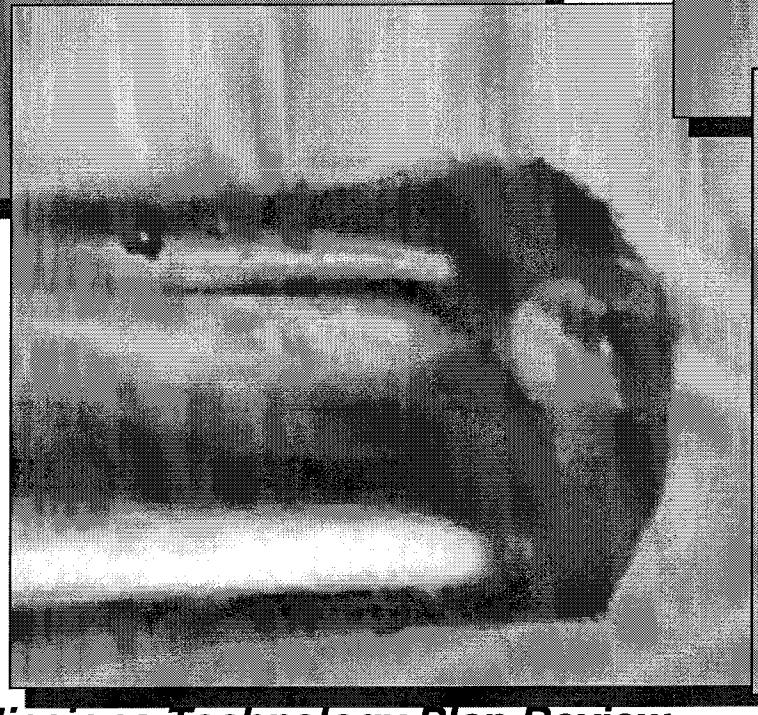
Mars Climate History Mission

PROTOTYPE CAPILLARY

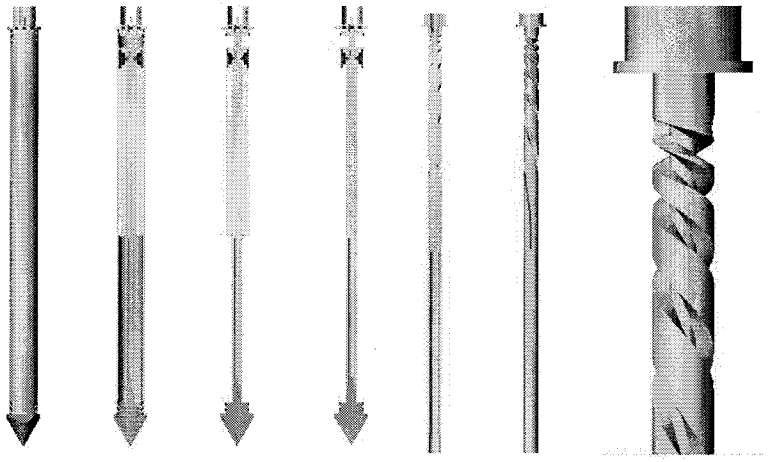






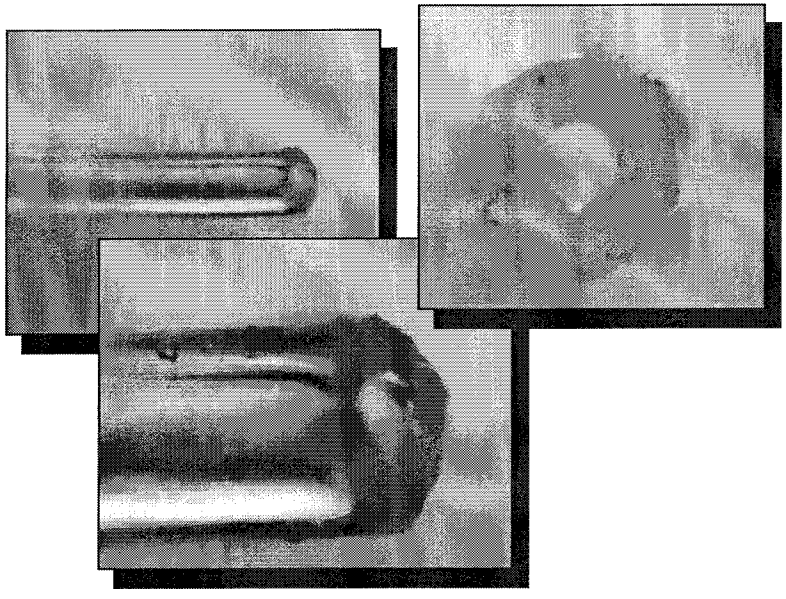
- 100 Micron ID, 300 Micron OD, thermoplastic (e.g. Nylon), ~ 40 MPa tensile strength
- Spool volume is ~100 cc, capacity ~ 8 cc
- Two capillaries allows bi-directional flow from tank at ~ 30 MPa (5000 psi) for continuous sampling
- 80 μm particles at 2 g/cc, 100 diameters apart at 0.1 m/s gives 0.1 g sample in capillary

SUBSURFACE EXPLORER (SSX) TECHNOLOGY PLANNING



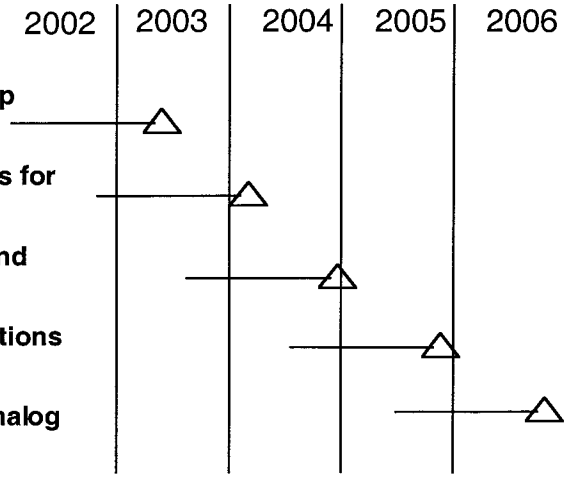
TECHNOLOGY STATUS

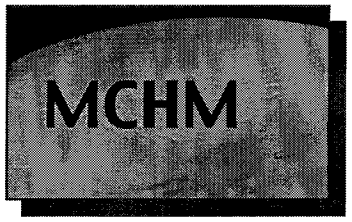
- Currently Developing Rotary Hammer Prototype and Capillary Sampler
- Advanced Technology Funding Transition
  - Need 3 Years to Develop Maturity for Flight Manifest
  - Extensive Testing in Many Natural Environments of:
    - Percussive Excavation
    - Capillary Sample Return to Surface



Advance Technology Milestones

Schedule





Mars Climate History Mission

STRAWMAN INSTRUMENTS

- **Lander**
  - **Luminescence Dater**
  - **Deconvolutional Confocal Microscope at 1 μm**
  - **Mass Spectrometers for Ice and Dust**
  - **Microscope at 10 μm**
  - **Ground Penetrating Radar**
  - **Raman Spectrometer**
  - **Electron Paramagnetic Resonance Spectrometer**
  - **Mössbauer Spectrometer**
- **Subsurface Explorer**
  - **Thermometer**

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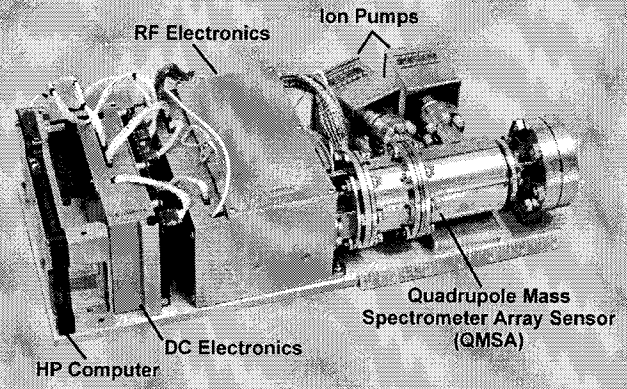
OTHER INSTRUMENTS 1

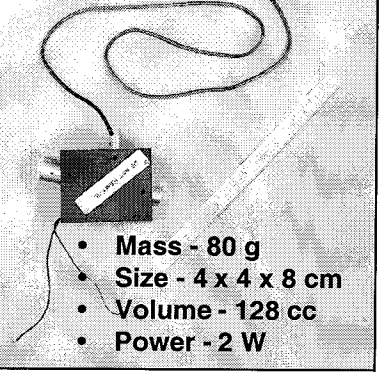
EXAMPLE MASS SPECTROMETER

- Mass 4 kg
- Volume 4,000 cc
- Power 6 W



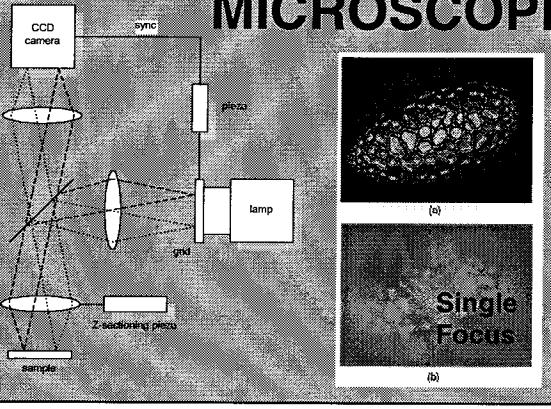
JPL

MICROSCOPE



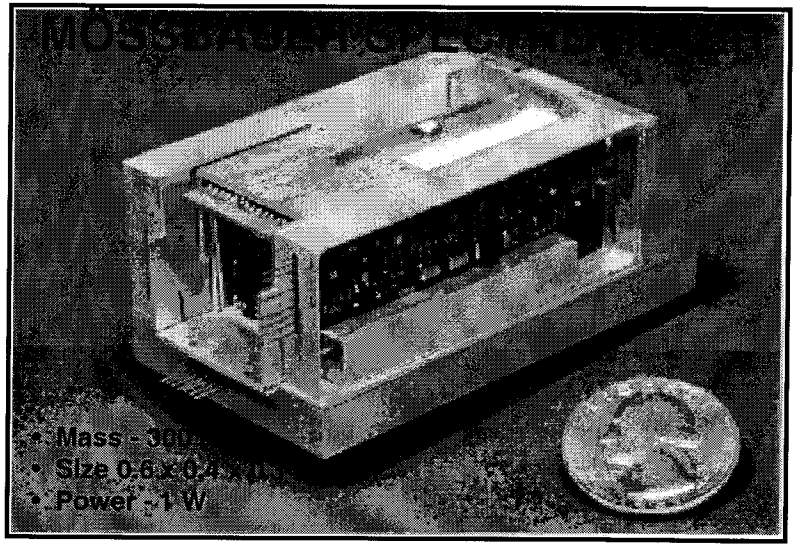
- Mass - 80 g
- Size - 4 x 4 x 8 cm
- Volume - 128 cc
- Power - 2 W

DECONVOLUTIONAL CONFOCAL MICROSCOPE



- Mass 0.25kg
- Volume 500 cc
- Power 2.5W

MÖSSBAUER SPECTROMETER



- Mass - 300
- Size 0.6 x 0.4 x
- Power - 1 W

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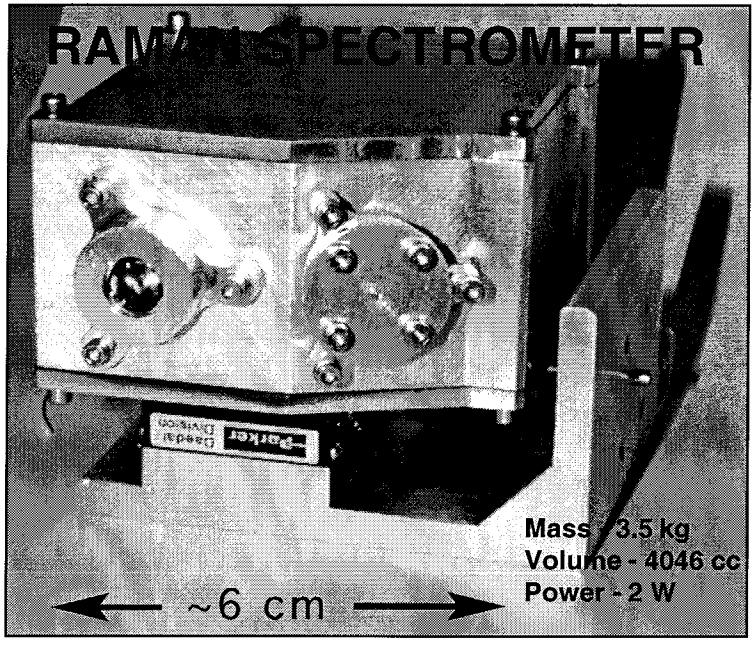
Mars Climate History Mission

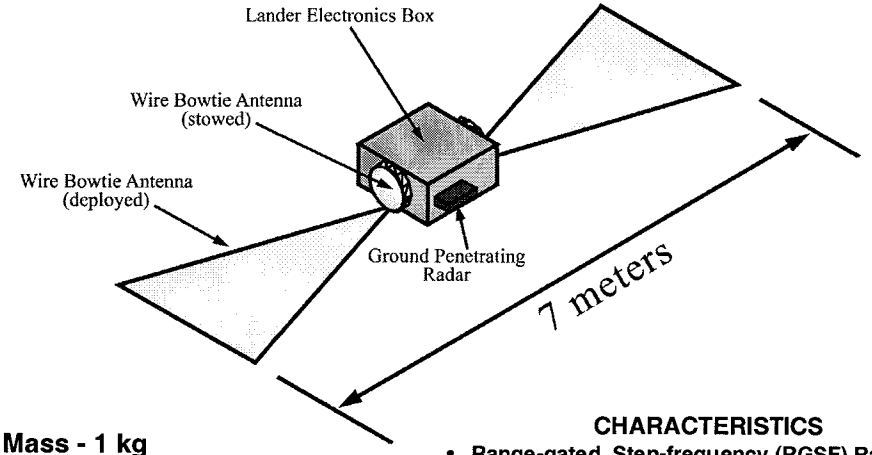
OTHER INSTRUMENTS 2

RAMAN SPECTROMETER



ELECTRON PARAMAGNETIC RESONANCE SPECTROMETER

GROUND PENETRATING RADAR

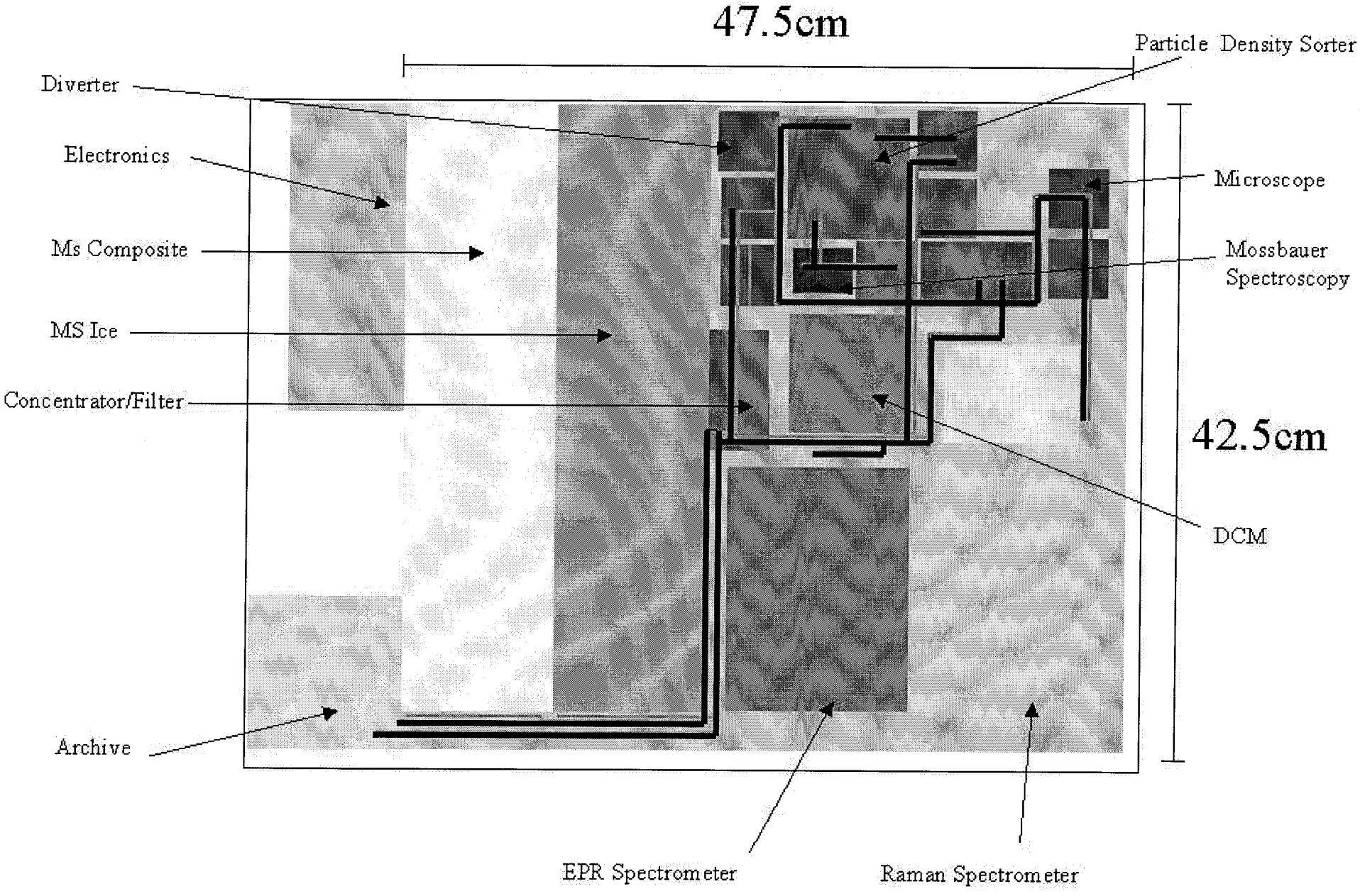


- Mass - 1 kg
- Volume - 4500 cc
- Power - 20 W Peak, 5 W Average

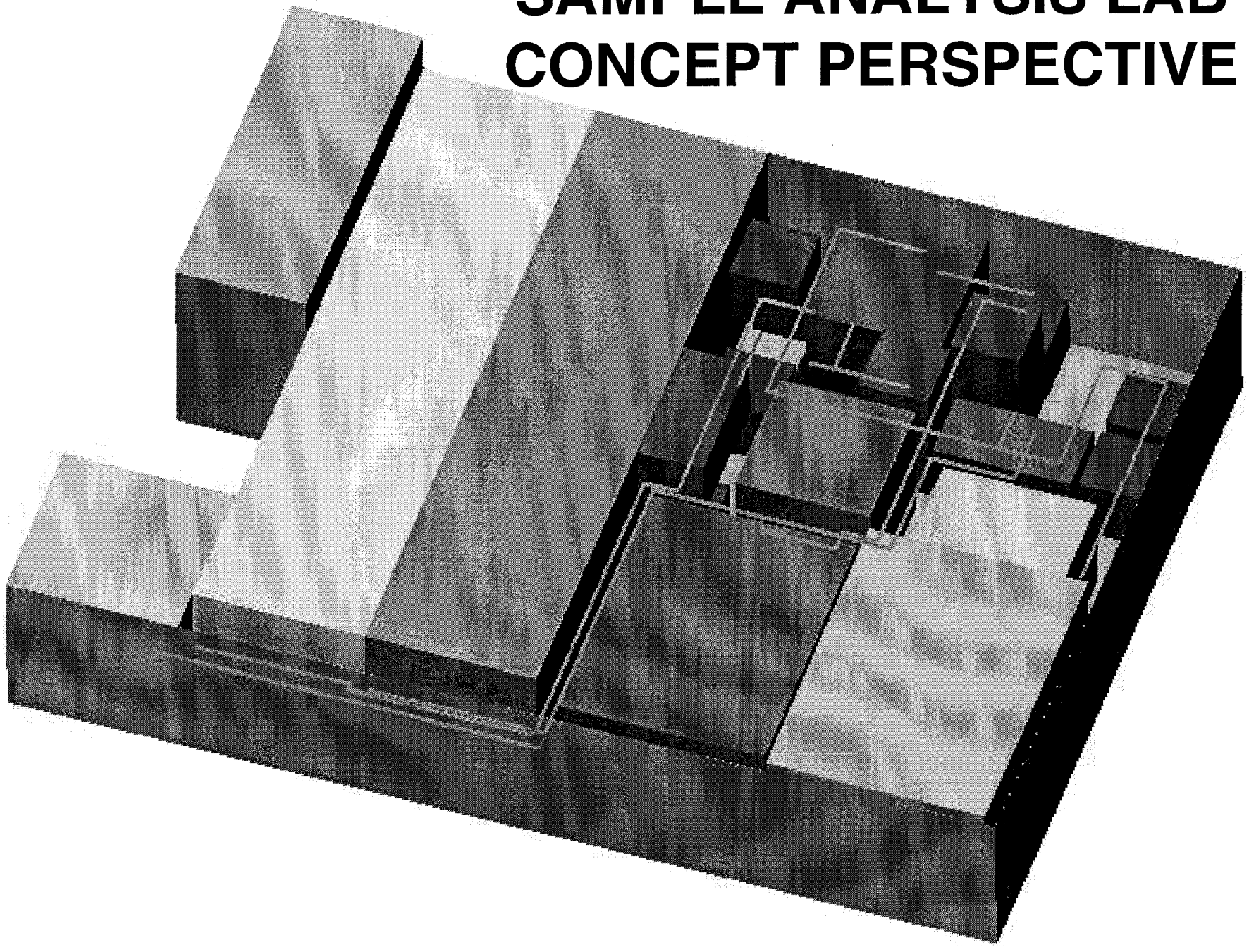
CHARACTERISTICS

- Range-gated, Step-frequency (RGSF) Radar
- 10-50 MHz Frequency, 3 MHz B_{RF}, 2 MHz Steps
- P_T = 5 W, 3 μs Pulse Width

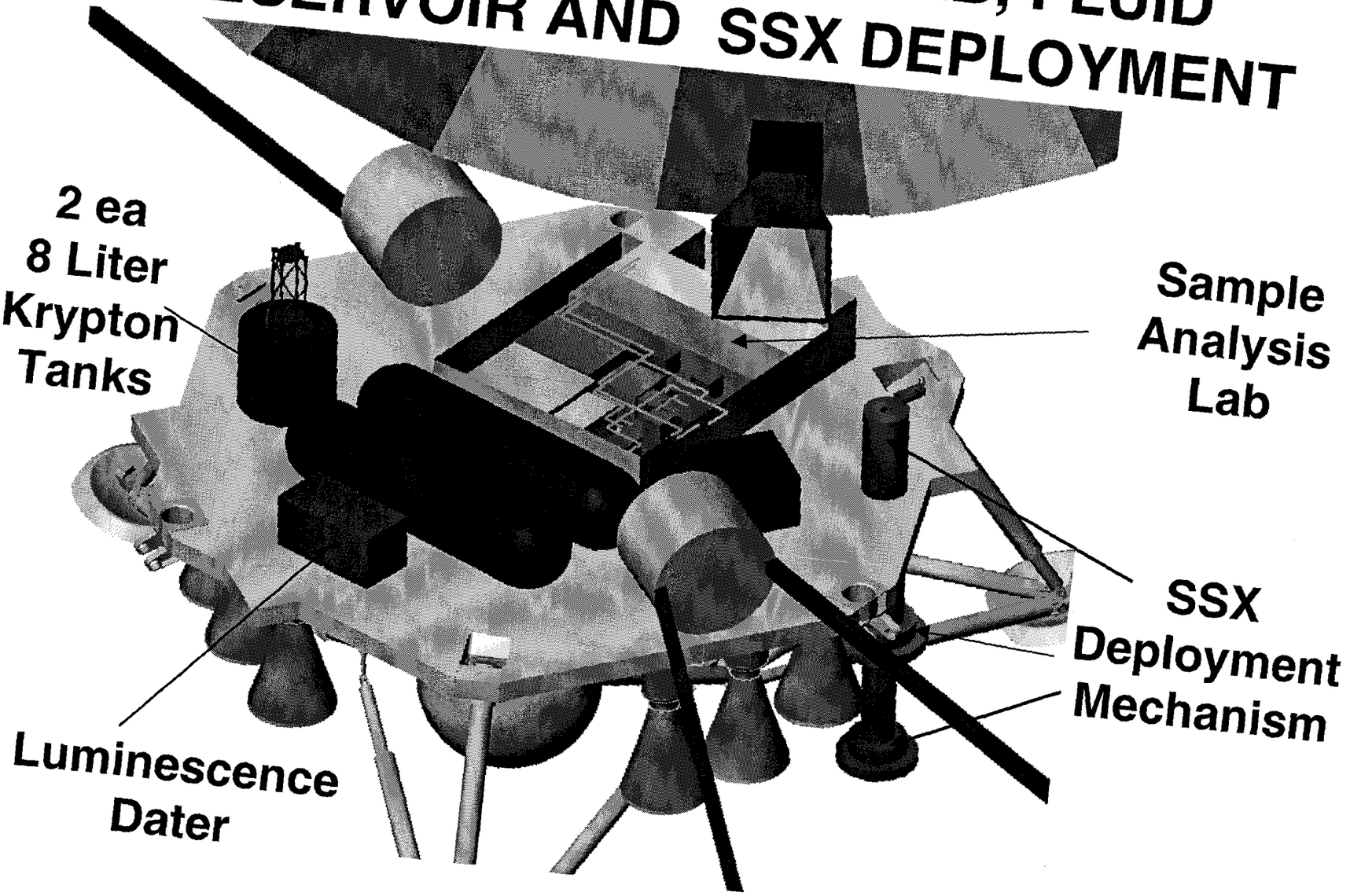
SAMPLE ANALYSIS LAB CONCEPT



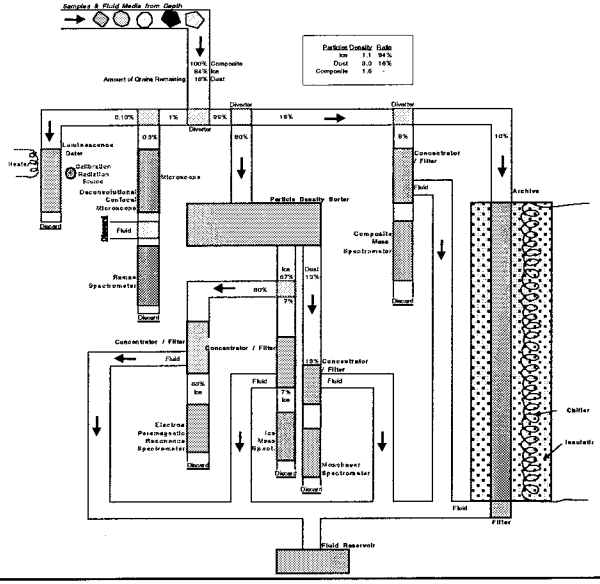
SAMPLE ANALYSIS LAB CONCEPT PERSPECTIVE



SAMPLE ANALYSIS LAB, FLUID RESERVOIR AND SSX DEPLOYMENT

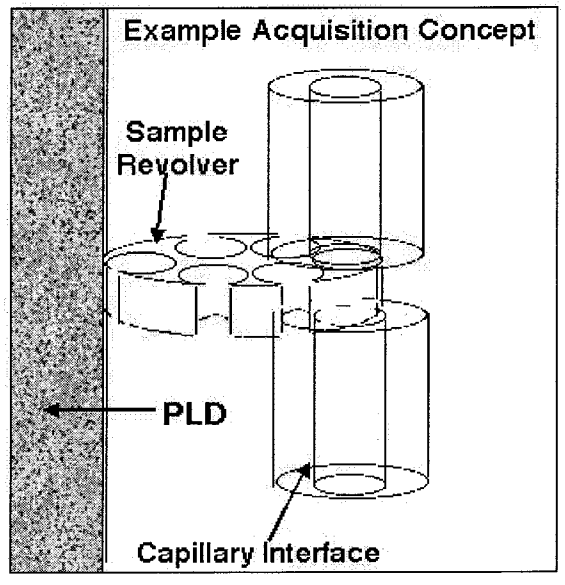


SAMPLE ANALYSIS LAB TECHNOLOGY PLANNING

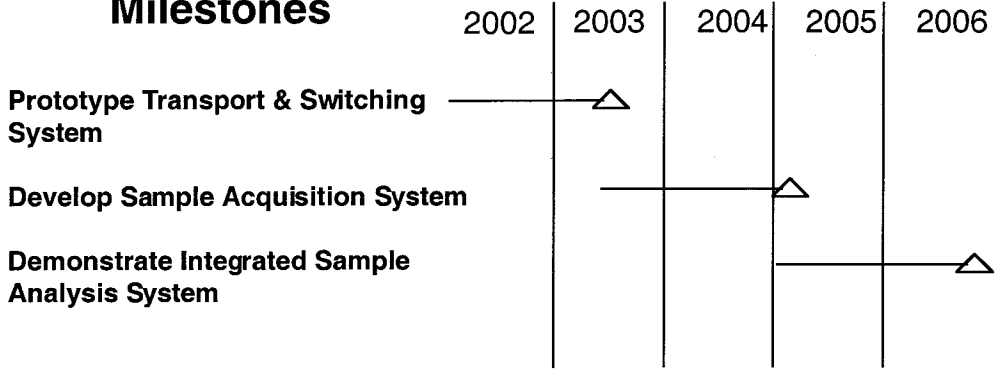


TECHNOLOGY STATUS

- **A Unified Approach to Handling and Manipulation of Samples Is Needed:**
  - **Autonomous Micro Manipulation of Widely Disparate Sample Shapes and Sizes Is Beyond the State of the Art**
  - **It Is Better to Handle a Single "Standard" Sample Shape/size**
- **This Development Is Possibly an Extension of Medical and Pharmaceutical Technology for Cell Sorting and "Mini" Fluidics**



Advance Technology Milestones Schedule



LANDING SITE SELECTION

- North Latitude >85° to Maximize Daylight
- On North PLD About 1 km Thick

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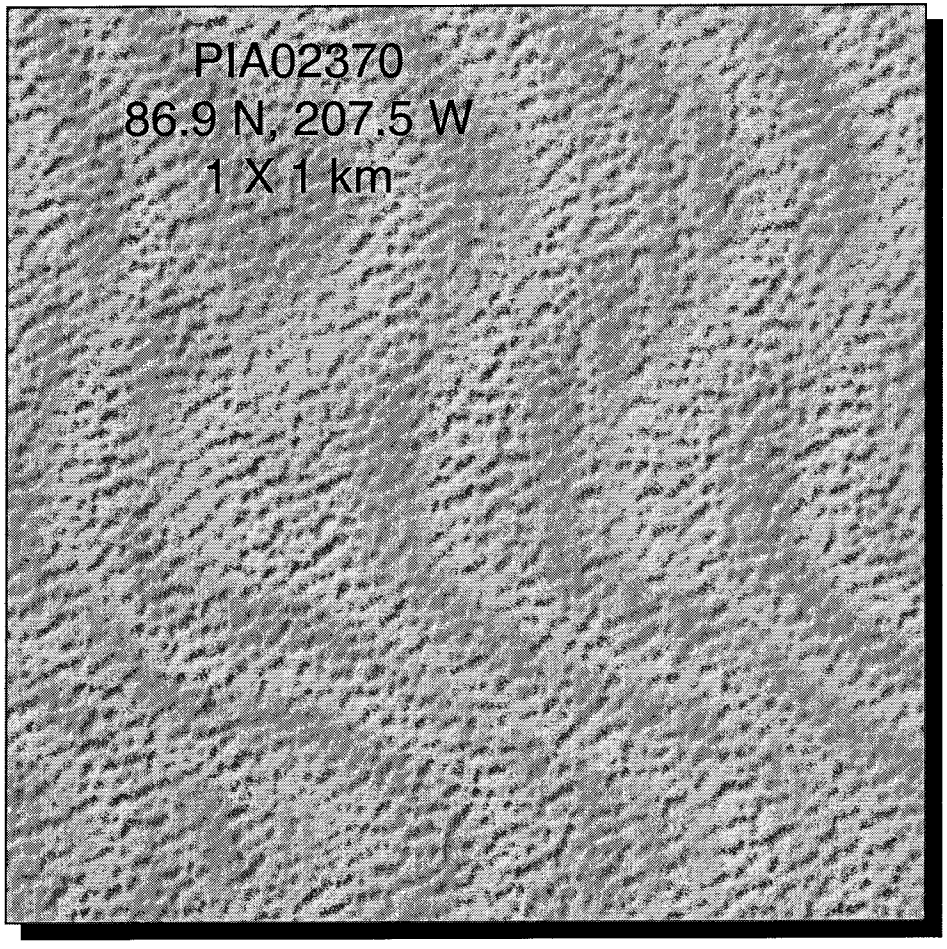
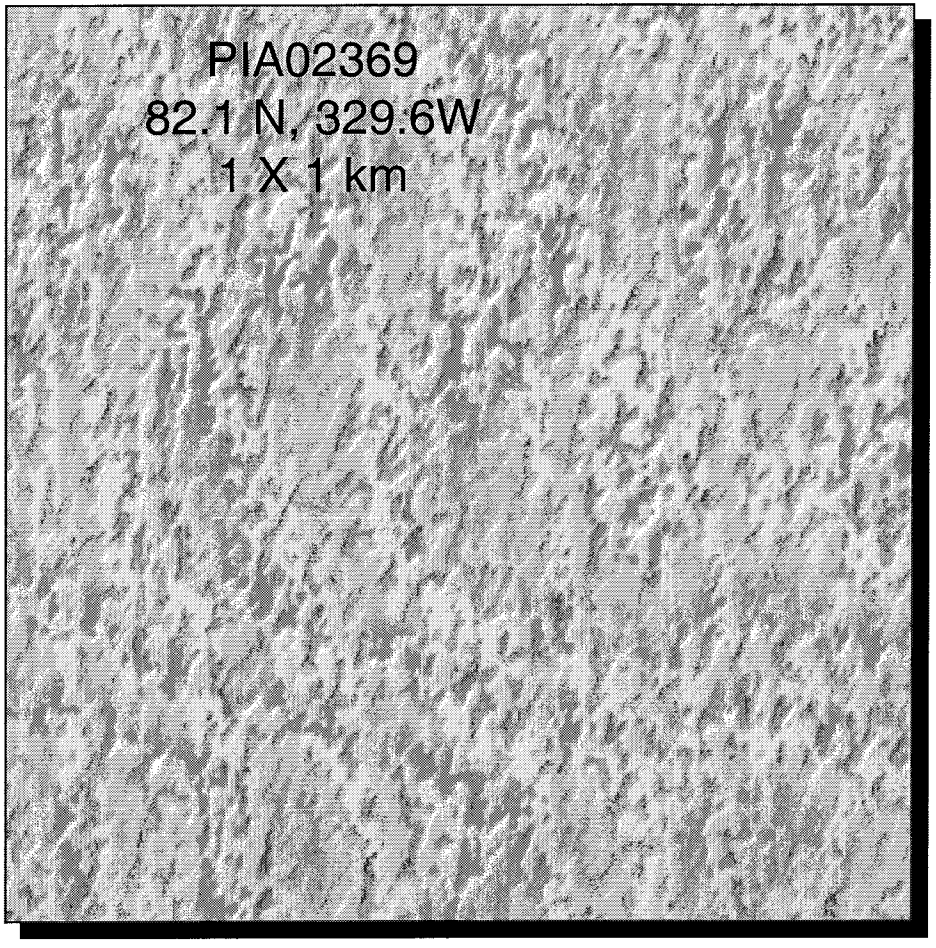
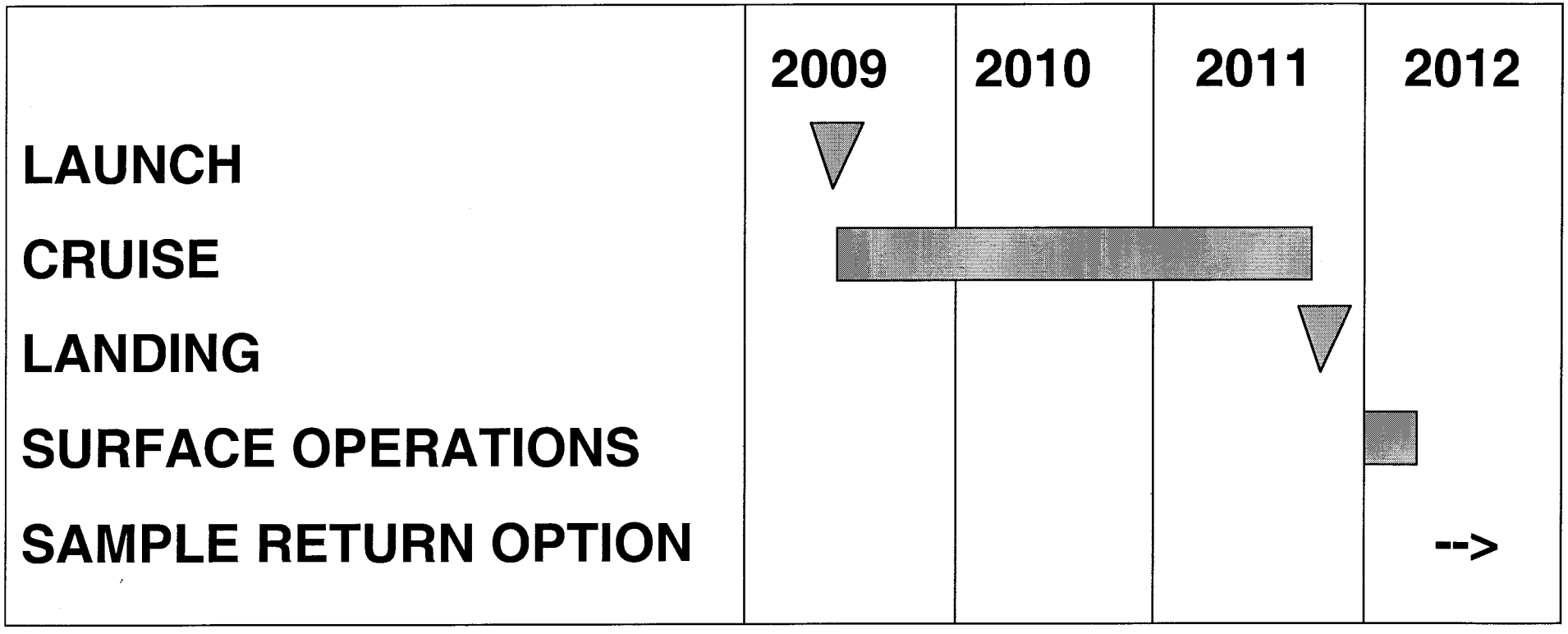
NORTH POLAR TERRAIN

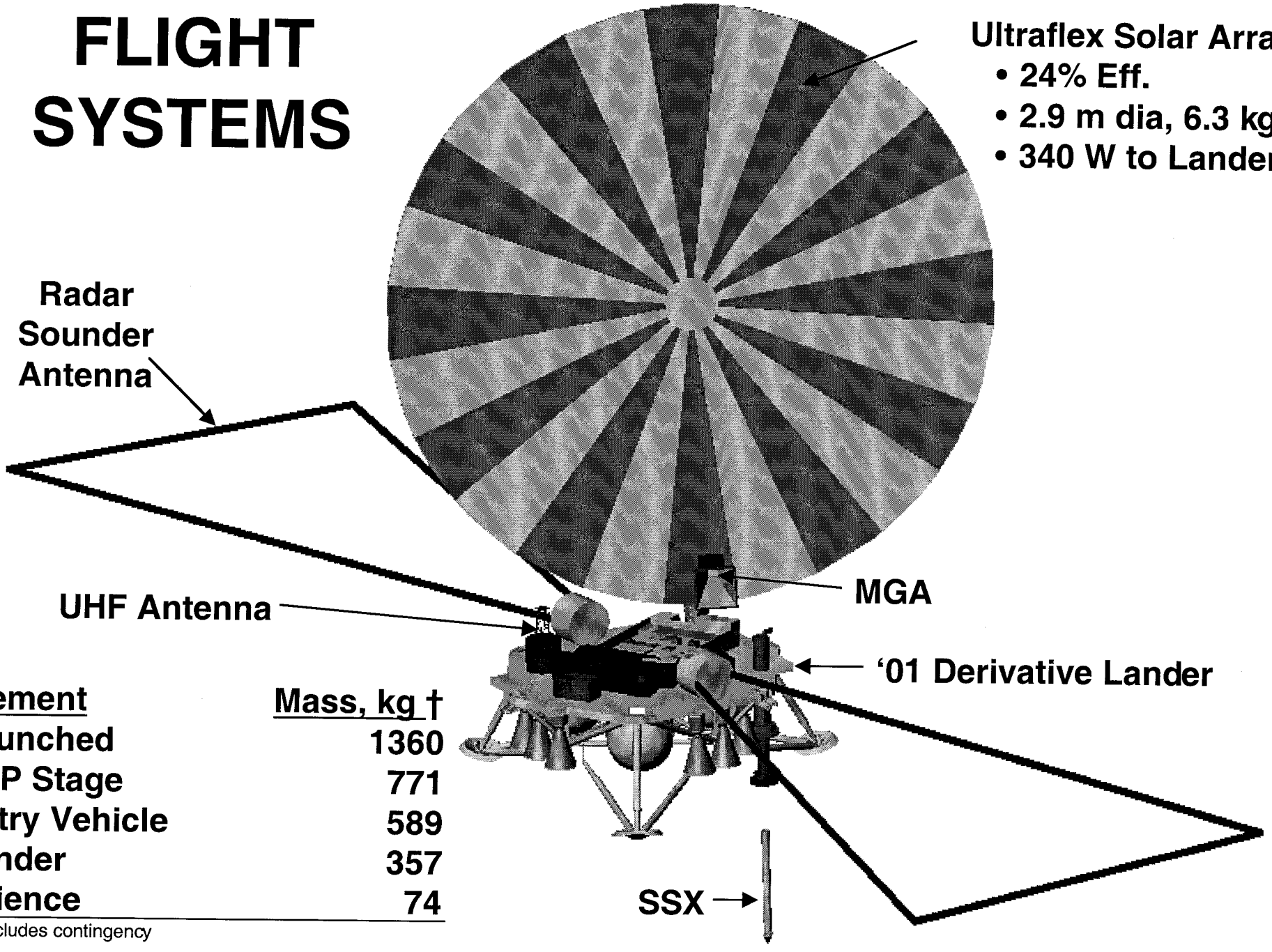




MISSION SCHEDULE



FLIGHT SYSTEMS



Element	Mass, kg †
Launched	1360
SEP Stage	771
Entry Vehicle	589
Lander	357
Science	74

† - includes contingency

TOPICS

Science

Subsurface Explorer

Instruments

Sample Analysis Lab

Mission and Flight System

Summary